# NATIONAL BUREAU OF STANDARDS REPORT

3665

PROPERTIES OF CONCRETE IN FLEXURE

AT HIGH RATES OF LOADING

(Progress Report)

by

D. Watstein and T. W. Reichard

Report to

Bureau of Yards and Docks
Department of the Navy

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
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# THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

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**Optics and Metrology.** Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

**Heat and Power.** Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

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**Electronics.** Engineering Electronics. Electron Tubes. Electronic Computers. Electronic Instrumentation. Process Technology.

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● Office of Basic Instrumentation ● Office of Weights and Measures.

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| NBS PROJECT | | NBS REPORT |
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Abstract

Two methods of applying impulsive loads to flexural concrete specimens were investigated. One of these utilized a drop-hammer machine and an attempt was made to produce a triangular load pulse by means of suitable buffers. The second method of producing the required load pulse utilized a spring loaded device, whose energy was transferred to the specimen in a prescribed time. Exploratory tests of a third method are in progress.

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## 1. INTRODUCTION

The object of the current study sponsored by the Bureau of Yards and Docks is to investigate the effect of dynamic loading on the physical properties of plain concrete in flexure. This project is a continuation of a previous study in which the effect of rate of straining on the compressive strength of concrete was investigated.

The work in the current investigation has been confined thus far to the development of a device suitable for applying a load pulse of controlled duration and magnitude. The load pulse was to be triangular in shape, with the rise time being about 0.1 of total duration of the pulse.

Two methods of producing the required load pulse are described. One of these utilizes a drop-hammer machine and the other a spring loaded device. It is planned to explore a third method of producing a dynamic load before undertaking a systematic study of properties of concrete.

## 2. DESCRIPTION OF TEST SPECIMENS

The preliminary tests in which various loading devices and techniques were evaluated were made with plain concrete beams 4- by 9-in. in cross-section and 44-in. long. The beams were tested on 24-, 30- and 36-in. spans.

The static compressive strength of the concrete, as determined with 6- by 12-in. cylinders, averaged about 7500 psi. It has been planned to use two different mixes of concrete in this investigation. The two mixes, classified as "weak" and "strong" concretes, were to have compressive strengths of about 2500 and 6500 psi, respectively.

## 3. METHOD OF TESTING

### 3.1 Drop-Hammer Machine

The drop-hammer used in a previous investigation[1/] produced a load pulse in tests of concrete cylinders whose shape

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1/ Effect of straining rate on the compressive strength and elastic properties of concrete, Journal of the American Concrete Institute, April 1953.

was determined by the elastic properties of the buffer interposed between the drop-hammer and the test specimen. In the first phase of the investigation it was decided to utilize the existing impact machine to obtain a triangular load pulse by means of suitable buffers. It was hoped that a material could be found which would be sufficiently inelastic to dissipate the energy of the drop-hammer and thus produce a load pulse having the required triangular shape.

Various materials including modeling clay and sand were tried with varying degrees of success. A fine dry sand in a piston type buffer gave the most promising results as shown by the approximately triangular load pulse in figure 1b. The use of the sand buffer was discontinued, however, since the duration of impact produced with it was too short and the magnitude of the peak value of the force could not be controlled with adequate accuracy.

The device used in conjunction with the sand buffer to limit the peak value of the applied load consisted of an attachment which interrupted the travel of the hammer at a prescribed instant and served to produce a relatively long decay period in the load pulse.

### 3.2 Spring Loaded Impact Machine

This device was developed in an effort to improve control over the duration and magnitude of the load pulse. The device is illustrated in figures 2 and 3. It consists basically of

a steel coil spring which is compressed by the hydraulic ram of a 50,000 lb capacity testing machine. The compressed spring bears against the hydraulic ram at its upper end, while its lower end bears on an auxiliary crosshead where it is locked by a trigger mechanism. When the trigger is released, the loading shaft which supports the spring is shot down against the test specimen. The test specimen supported by the lower crosshead of the machine is brought up to bear against the shaft just prior to release of the trigger. It will be noted that a dynamometer and a suitable buffer are interposed between the test beam and the loading shaft.

The trigger mechanism is illustrated in figure 4. It consists essentially of a pair of 1-in. steel bearing balls spring loaded into a groove cut in the loading shaft. The groove in the shaft was sufficiently deep to permit nearly half of the steel balls to interlock with the shaft. In this manner, a slight pressure on the balls was sufficient to lock the shaft in position while it carried a large load. A simple lever system was used to relieve the pressure on the steel balls and release the loading shaft.

Some needed changes in the design of the device became apparent as the work progressed, but the basic ideas of this device have been proven sound. The device, as used now, is

designed for a maximum load of 5000 lb which is sufficient for the flexure tests in progress. Figure 1a shows a typical test record obtained from the dynamometer using this machine. The rise time is about 0.004 sec and the decay time about 0.016 sec.

## 4. INSTRUMENTATION

The instrumentation used in recording the applied loads and strains in the concrete beams was essentially the same as used previously in the "hard" impact tests of compressive strength made in the drop-hammer machine. (See Ref. 1 in Introduction). Slight modifications were made in the preamplifiers to improve their low frequency response and an automatic six-step calibrator (Figure 5) was constructed. A highly filtered, voltage regulated power supply was tried out as a gage circuit voltage source, but due to rapid line voltage fluctuations the idea was abandoned. A block diagram of the instruments as used at present is shown in figure 6.

At the present time a change in instrumentation is contemplated. An amplifying system reliable down to d.c. is necessary to accurately amplify the long decay portion of the required load pulse. A system using a carrier frequency of at least 10 kc is the probable answer.

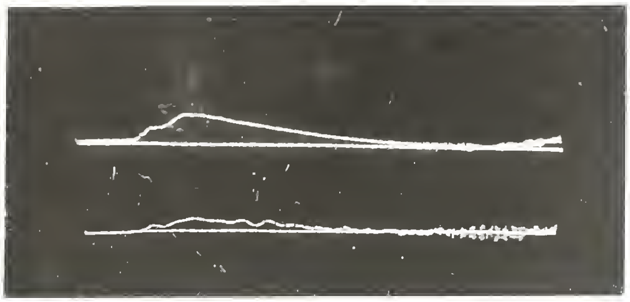


Fig. Ia TEST DATA FROM SPRING LOADED MACHINE

Fig. Ib LOAD PULSE FROM DROP HAMMER USING SAND BUFFER

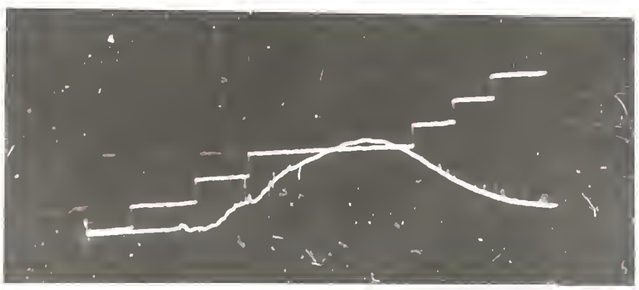
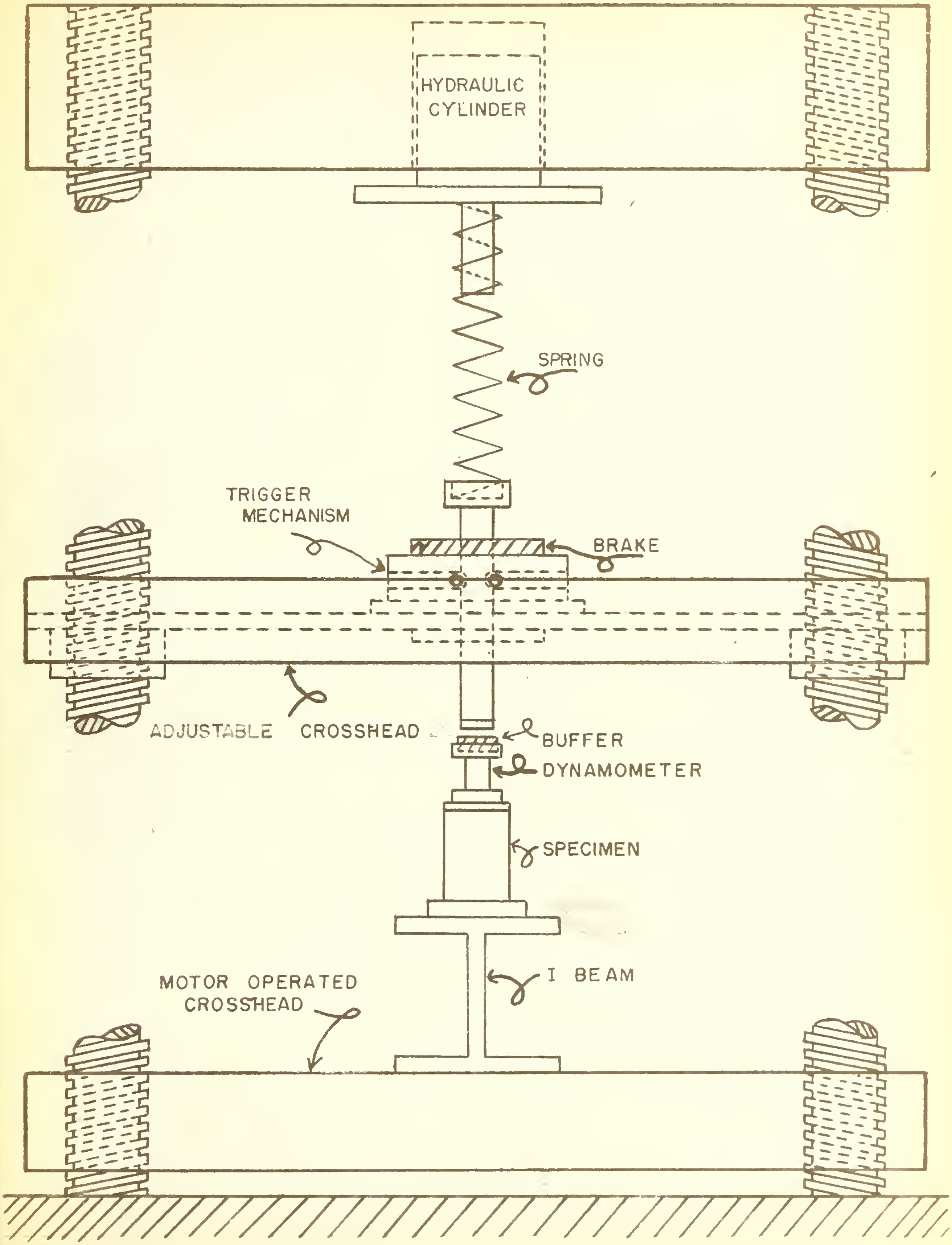


Fig. Ic SIX STEP CALIBRATION SIGNAL SUPER-IMPOSED ON LOAD PULSE




SPRING LOADED IMPACT MACHINE

FIG. 2

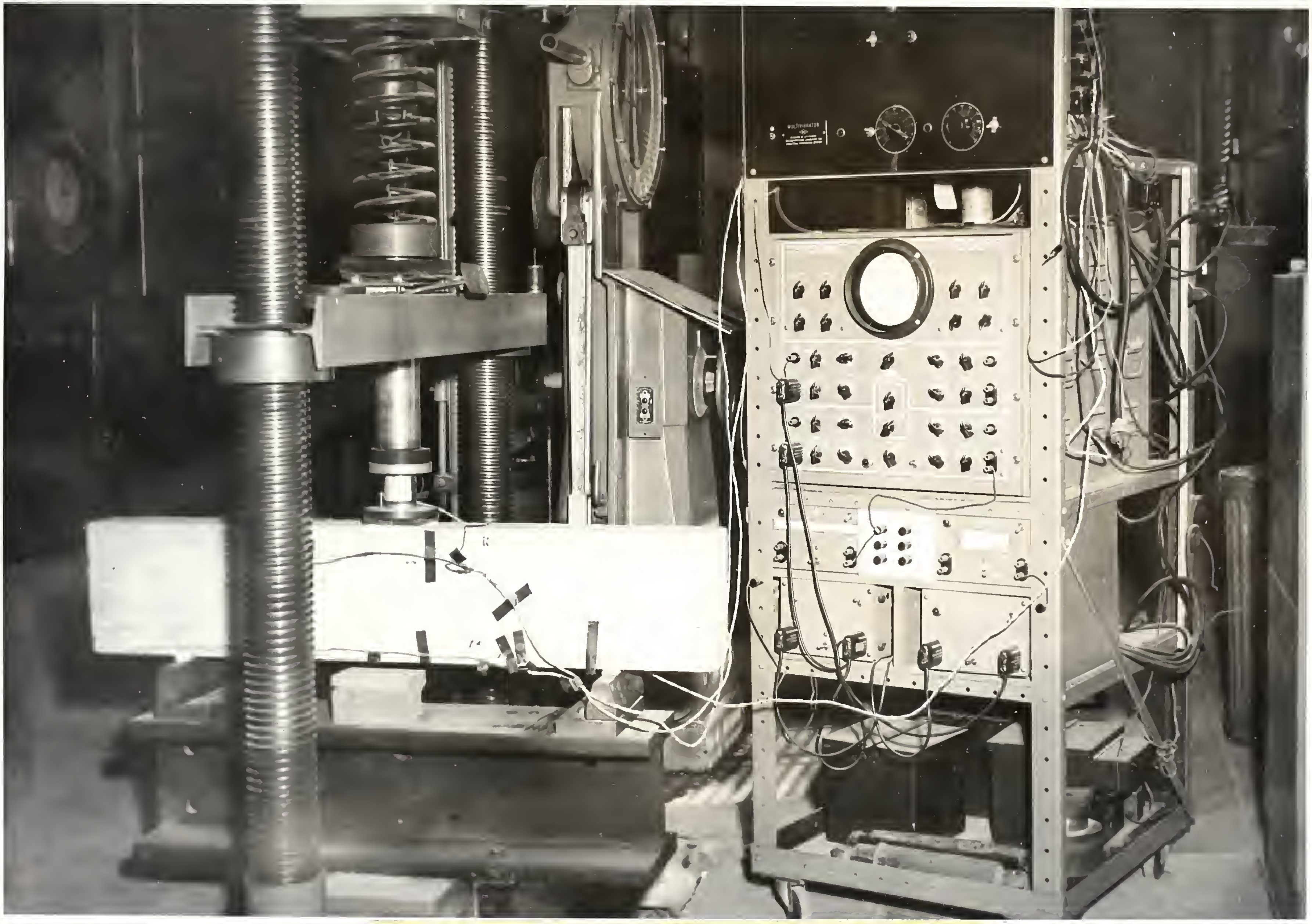
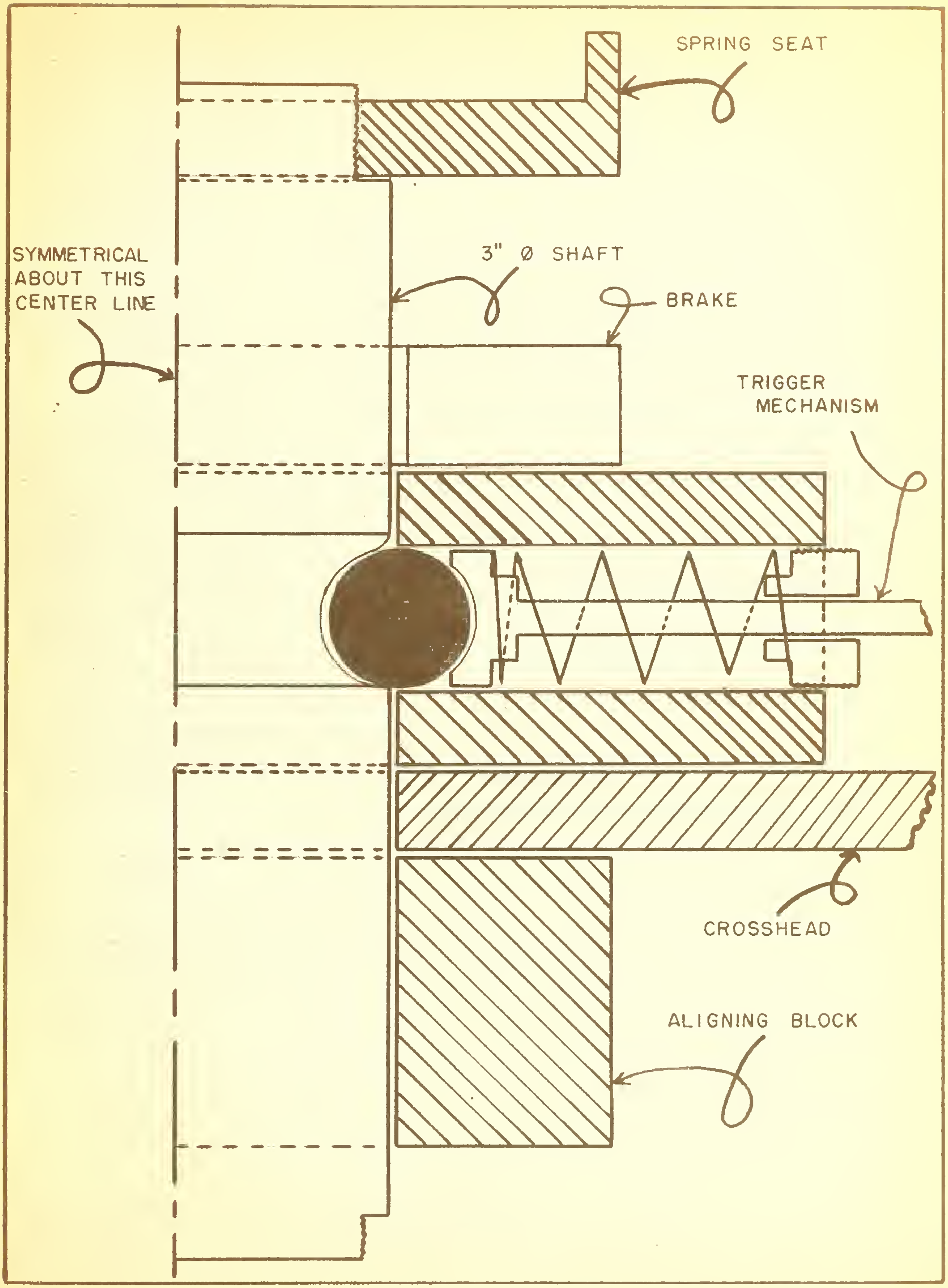
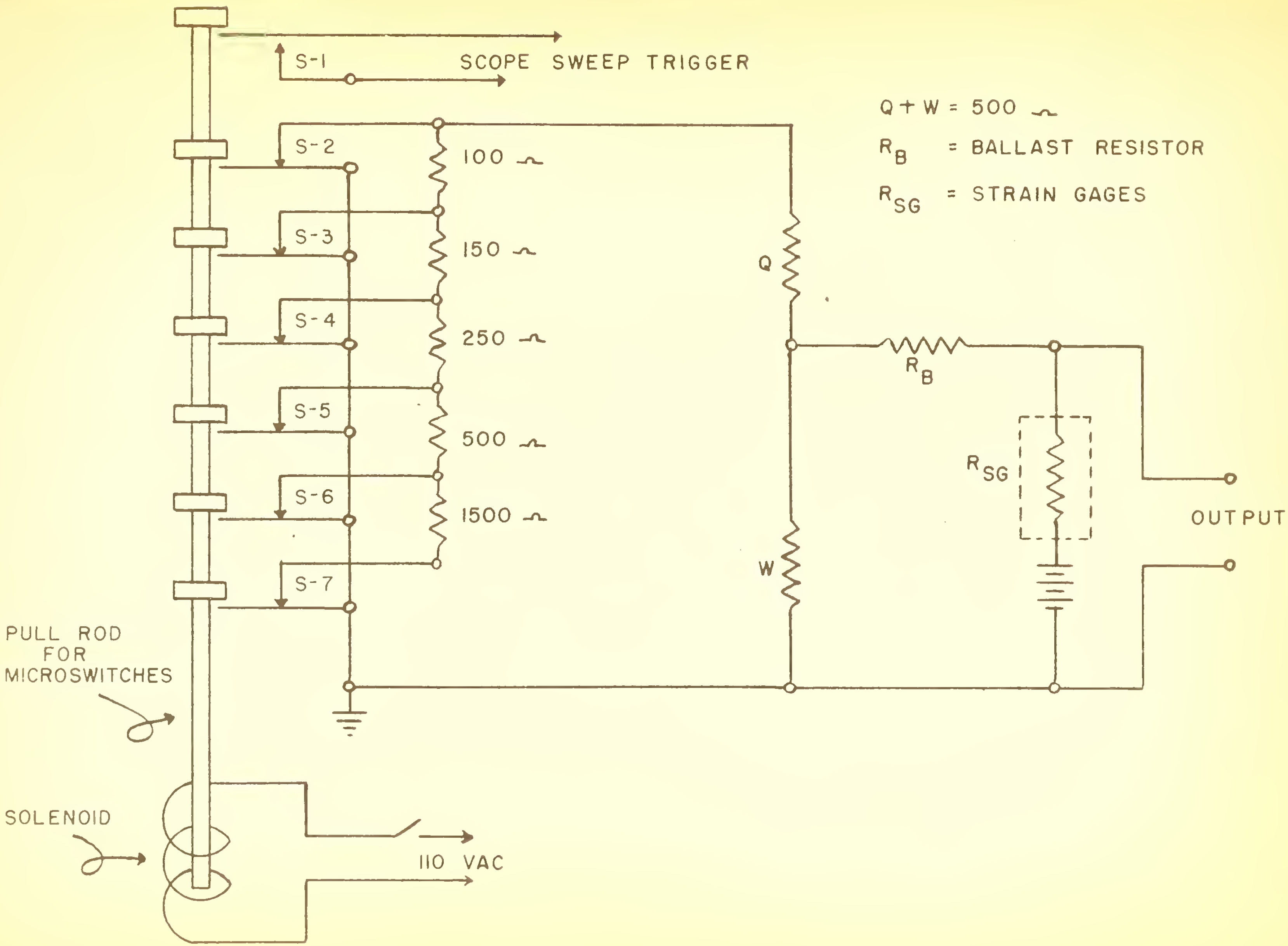


Fig. 3 SPRING LOADED IMPACT TESTING MACHINE



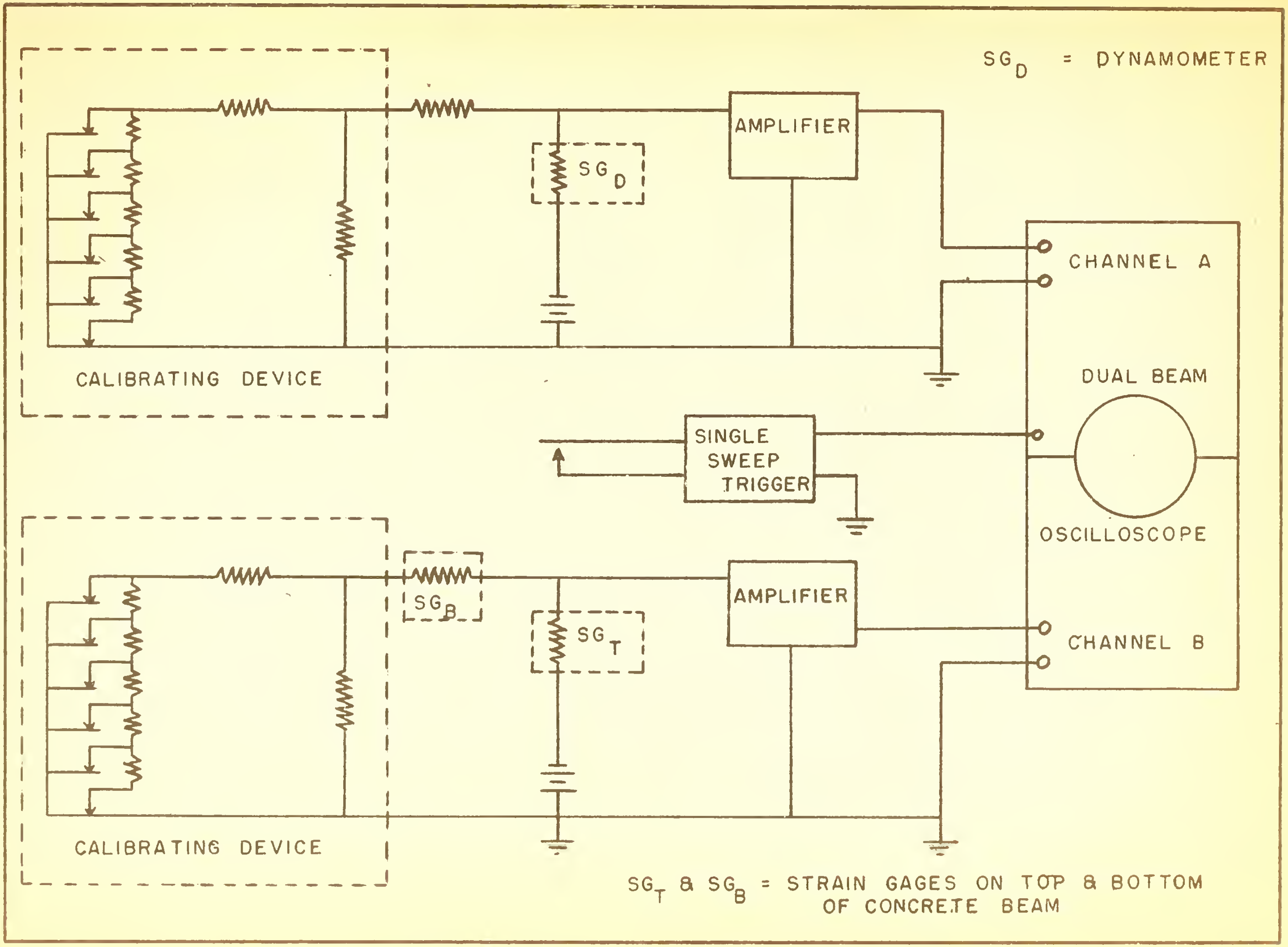

TRIGGER ASSEMBLY $(\frac{1}{2})$ FOR SPRING LOADED IMPACT MACHINE

FIG. 4




SIX STEP CALIBRATING DEVICE

FIG. 5




INSTRUMENTATION FOR FLEXURAL IMPACT TESTS

FIG. 6

## THE NATIONAL BUREAU OF STANDARDS

### Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

### Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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